CHAPTER 1

MICROWAVE COMMUNICATIONS SYSTEMS

1.1 SYSTEM CHARACTERISTICS

Communications systems in the 1 GHz to 10 GHz portion of the radio frequency spectrum utilize the property that propagation approaches an optical straight-line path. Propagation takes place in the lower atmosphere (troposphere) and is affected by meteorological factors such as pressure, temperature, water vapor, turbulence, and stratification. Communications in this media are generally either line-of-sight or tropospheric scatter.

1.1.1 Line-of-Sight System

A line-of-sight (LOS) microwave system consists of one or more point-to-point hops. Each hop is designed so that it can be integrated into a worldwide communications network. LOS system characteristics are:

o Propagation. Free space as affected by the troposphere.

o Communications Capacity/Bandwidth. Up to 600 - 4 kHz voice channels; wideband, can accept TV.

o Range. Usually 50 to 150 km (31 to 95 statute miles). This depends upon antenna height, earth curvature and intervening terrain.

o RF Power. Usually less than 10 watts.

o Antennas. Both transmitting and receiving antennas are horn driven paraboloids providing high gain and narrow beam widths. In some applications plane reflectors are used in combination with the paraboloids.

o Reliability. Designed for operational availability in excess of 99 percent of the time, including effects of poor propagation.

o Countermeasures. Due to directivity of antennas the system is difficult to jam. Should not be susceptible to nuclear disturbances of the ionosphere.

o Site Size. Requires minimum amount of space. Site size is usually governed by the antenna tower guy wire requirements.

o Relative Costs. Construction operation, and maintenance costs as shown in figures 1-1, 1-2, 1-3, and 1-4 of an LOS system are relatively low. Costs include the "Location Factor" commonly used in worldwide construction estimating.

o Application. Due to the bandwidth capability and siting requirements, LOS is well adapted to: moderate distance point to point multichannel communications (with repeaters); transmission of closed circuit TV; transmission of radar information from outlying locations; communications relay between locations in congested areas and "Antenna Farms".

1.1.2 Tropospheric Scatter System

A tropospheric scatter microwave system consists of one or more point-to-point hops (or sections). Each hop is designed so that it can be integrated into the world wide communications network of the Defense Communications System (DCS). Tropospheric scatter links have these characteristics:

o Propagation. Free space as affected by the troposphere

o Communications capacity/bandwidth. Up to 600 - 4 kHz voice channels; wideband, can accept TV.

o Range. Up to 800 km (500 statute miles)

o RF Power. High, up to 75 kilowatts depending upon bandwidth, quality, and range.

o Coverage. Point-to-point only.

o Antennas. Both transmitting and receiving antennas are horn driven paraboloids providing high gain and narrow beam widths. Antenna "dishes" may be as large as 50 to 60 feet in diameter.

o Reliability. Designed for operational availability in excess of 99 percent of the time including periods of poor propagation.

o Countermeasures. Extremely difficult to jam due to high directivity. Should not be susceptible to nuclear disturbances of the ionosphere.

o Site Size. Moderate. The area in front of transmitting antenna must be kept clear due to electromagnetic radiation hazards. The size of this area is dependent upon the beamwidth and RF power.

o Relative Costs. Moderate to high. Start up and operating costs generally higher than for HF communication systems. The greater number of stations required for tropospheric scatter systems is offset by the higher information rate.

o Application. This mode of propagation meets the communications requirements between HF within its minimum skywave one hop distance in the order of 400 miles and the one hop line-of-site of about 30 miles. It is especially useful where

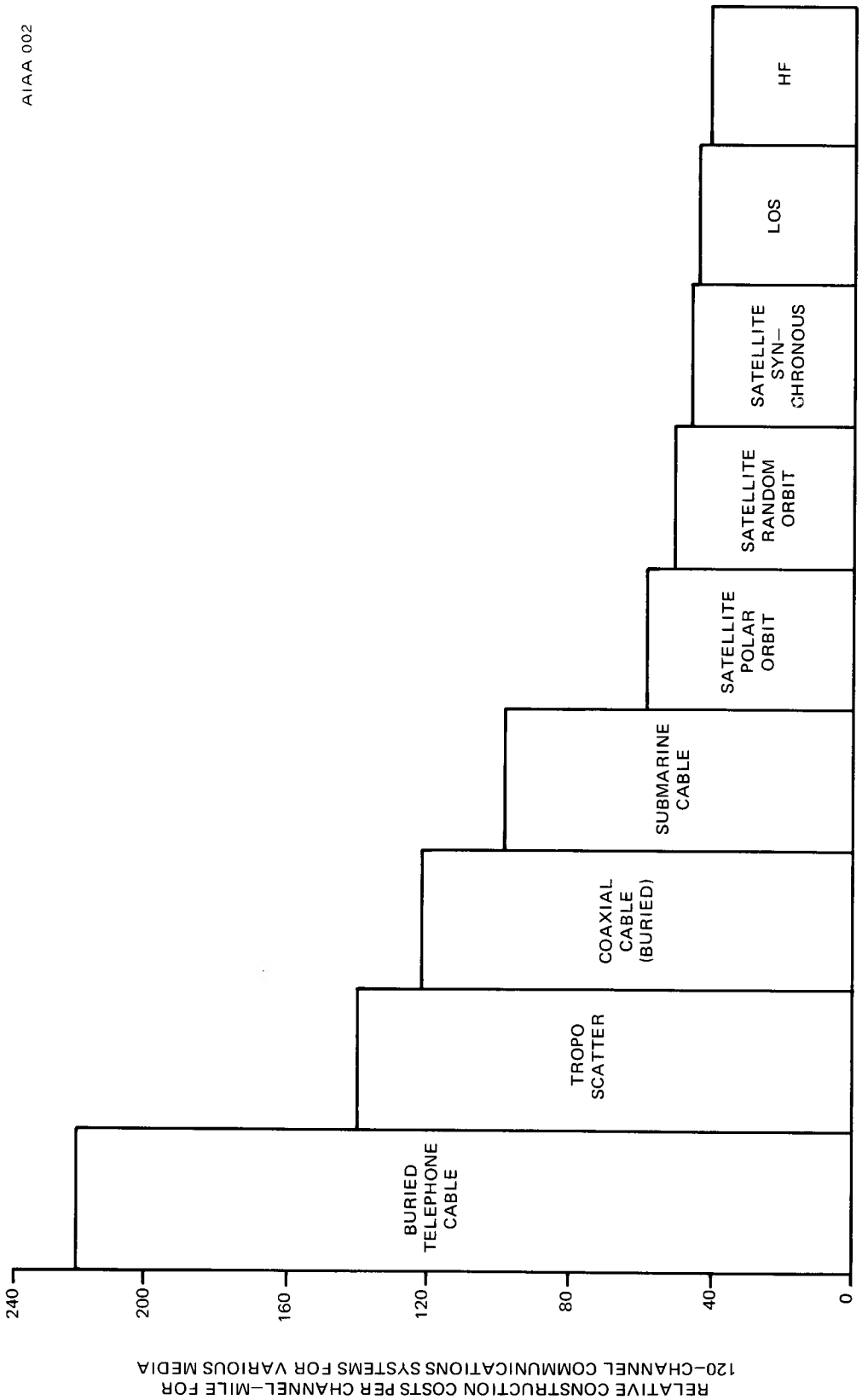


Figure 1-1. Relative Costs of Constructing Various Communication Systems

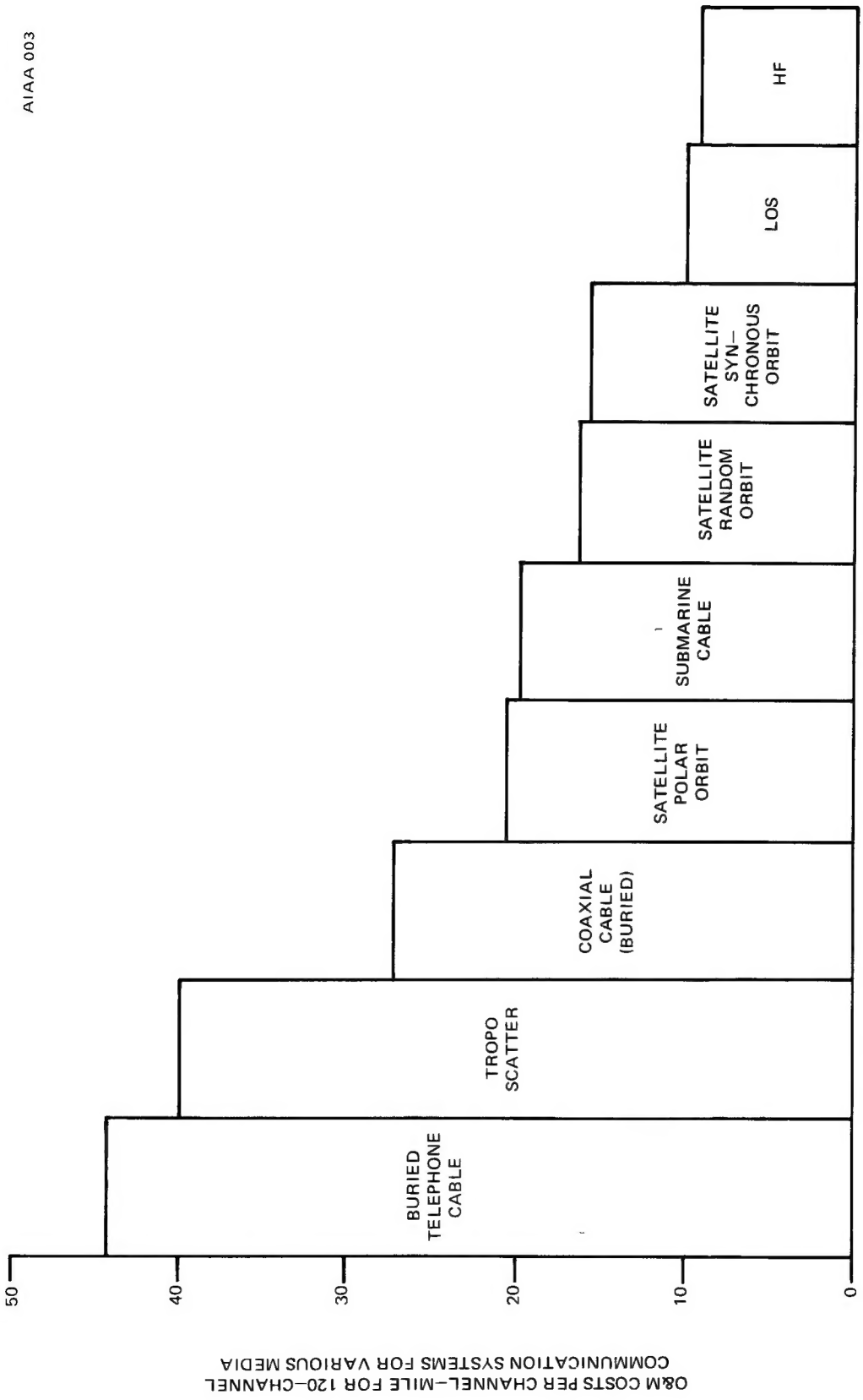


Figure 1-2. Relative Costs of O&M for Various Communication Systems

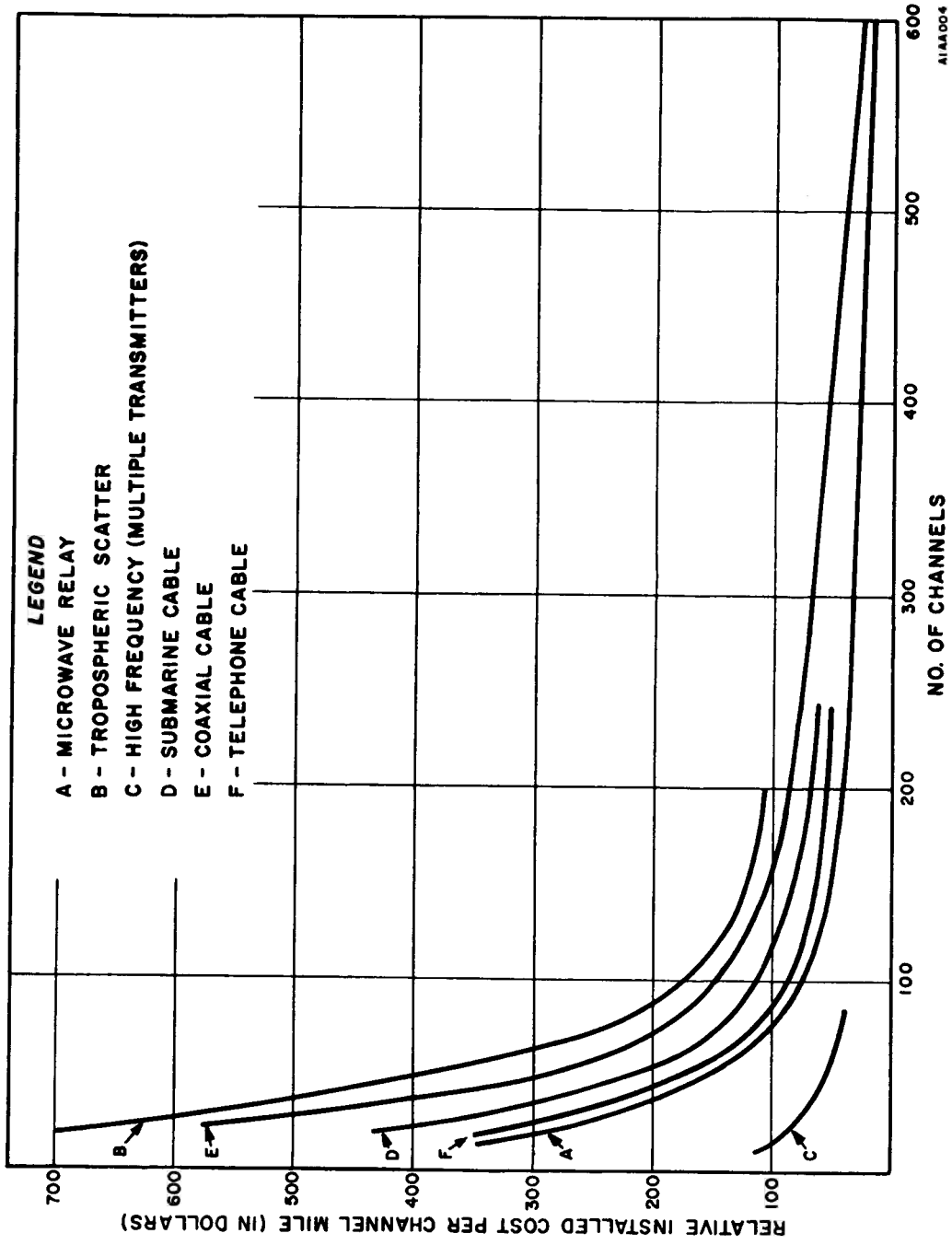


Figure 1-3. Relative Construction Costs for Various Media

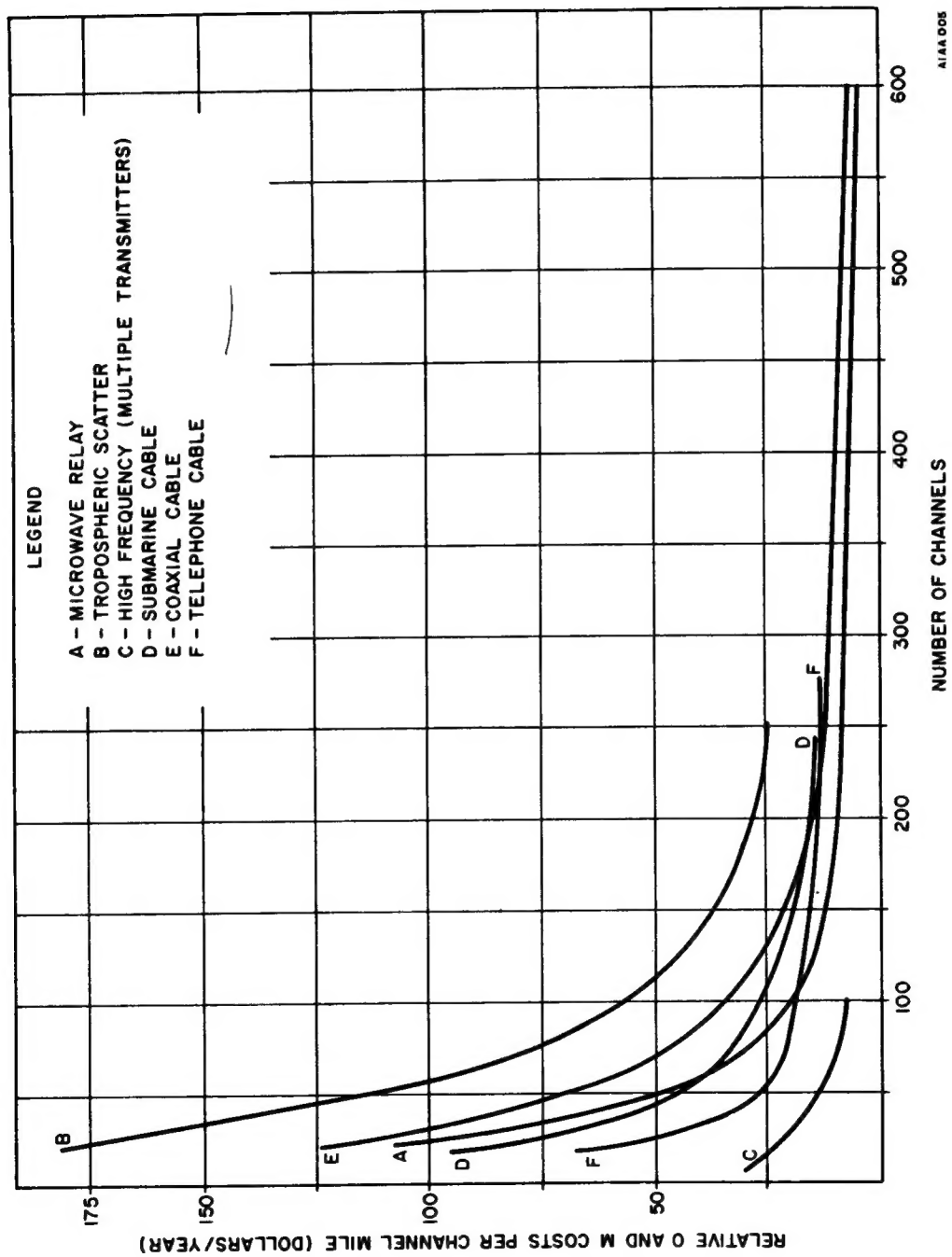


Figure 1-4. Relative Operation and Maintenance Costs for Various Media

tropographic conditions preclude the use of line-of-sight or adverse propagation conditions interfere with other transmission methods.

1.2 SYSTEMS TRANSMISSION STANDARDS

In order to assure high quality performance and to interface with the Defense Communications System, LOS and tropospheric scatter microwave communications equipments, facilities and systems shall meet the interface and performance requirements of the Defense Communications Agency (DCA) Engineering-Installation Standards Manual (DCA Circular 330-175-1).

1.2.1 Defense Communications System Reference Circuit

The DCS reference circuit for wideband systems consists of six links, each 1000 nautical miles, reference figure 1-5. The links are interconnected on an audio frequency and baseband (group) basis.

Each link is further subdivided into three sections nominally 333 nautical miles (NM) long consisting of radio/wire facilities with intermediate repeaters as required and equipped with Frequency Division Multiplex (FDM) equipment. Each section in figure 1-5 has different multiplex terminations to illustrate various interconnections that are possible. Transmission specifications for the DCS Reference Circuit are listed in Table 1-1.

1.2.2 Line-of-Sight System Reference Circuit

The DCS Reference Circuit as applied to LOS microwave systems is illustrated in figure 1-6. The 333 NM Section is divided into 13 hops, each nominally 26 NM in length.

In practice, geographical and communications requirements will dictate the actual terminations and lengths. Figure 1-7 illustrates a typical case. Consequently the DCS transmission specifications must be pro-rated on a per mile, per hop or per section basis. The basic allowable transmission media noise for LOS sections is defined as:

Section Length in NM	Allowable Noise
L > 151 N M	3.33L pwpO
27 < L < 151 N M	2.76L pwpO + 85.5 pwpO
L < 27 N M	0.160 pwpO

This is a slight variation from that specified in Note 2, table 1-1, but it was found necessary since extremely short links sometimes necessary in LOS systems were not envisioned in the basic specification. Figure 1-8 shows a LOS hop and the interfaces between circuit links. Figure 1-9 lists the various interface parameters and their

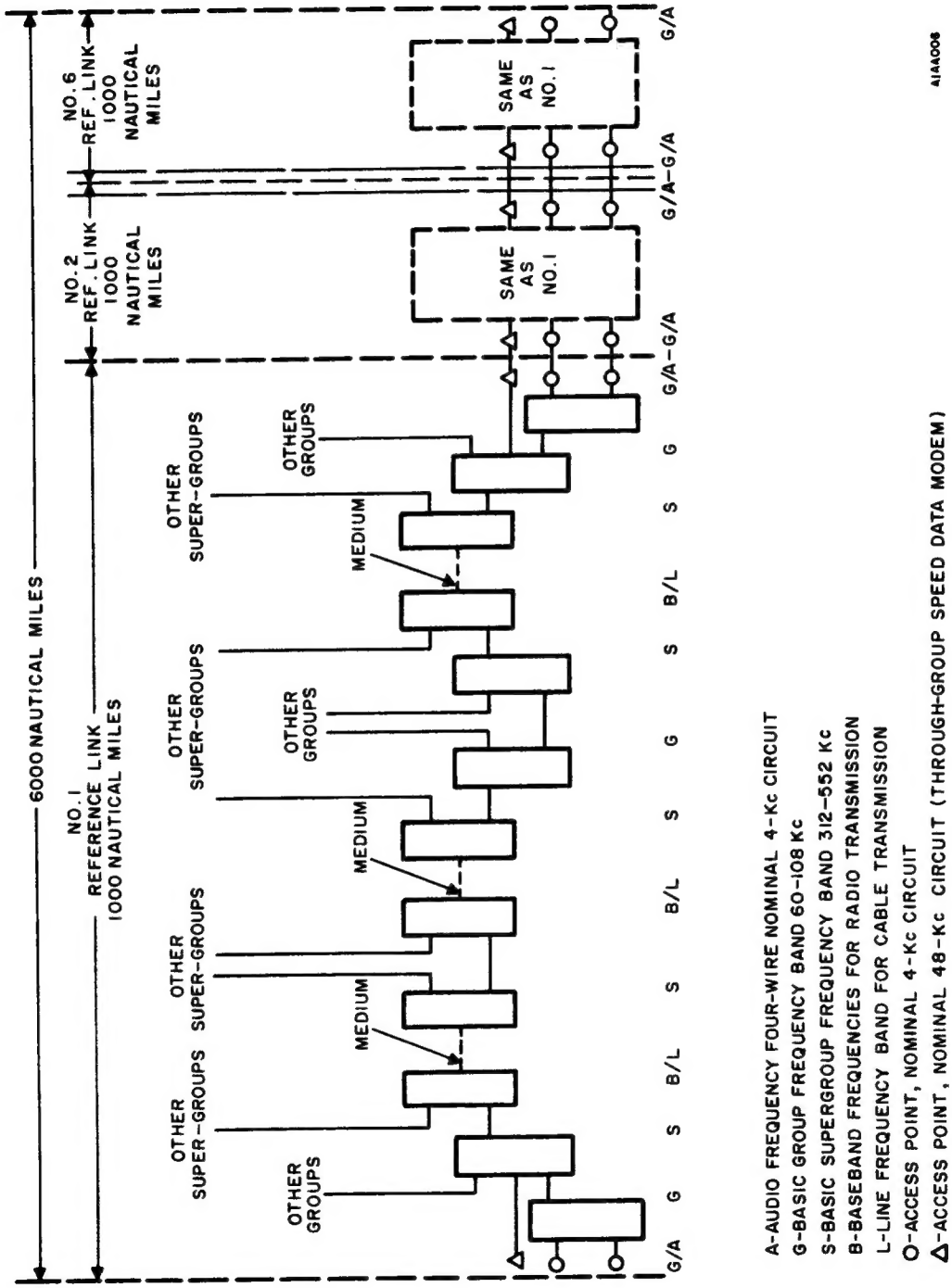


Figure 1-5. DCA Reference Circuit - Transmission Subsystem, Nominal 4-kHz and 48-kHz Channels

Table 1-1. Transmission Specifications for DCS Reference Circuit Transfer Function

PARAMETER	OVERALL REFERENCE CIRCUIT 6,000 NM (6 LINKS)	NORMALLY ASSIGNABLE TO	
		TRANSMISSION MEDIUM, INCLUDING REPEATERS (6LINKS)	MULTIPLEX EQUIPMENT (1 LINK ONLY)
Insertion loss-frequency, ref. to 1,000 Hz			
600-2400 Hz	+4.0 -4.0dB		+0.7 -0.7dB
400-3,000 Hz	+9.0 -4.0dB		+1.5 -0.7dB
300-3,400 Hz	+18.0 -4.0dB		+3.0 -0.7dB
Envelope Delay Distortion, 1,000 2,600 Hz max.	1,000 μsec		160 μsec
Median noise level, from all sources, worst hour, worst month:			Term Only / Term & Intermed
Psophometrically weighted at OTLP, pwp	25,000	20,000	475 / 815
Equiv. white noise, F1A line wtg, dBaO	38.0	37.0	20.8 / 23.1
Harmonic distortion			-40 dBm
Gain change for output level increase +3.5 dBmO +12.0 dBmO from 0 dBmO, to			0.35 dB max 5.0 dB min
Net loss variation, max at 1,000 Hz audio, or at any baseband frequency.	±2.0 dB	±0.5 dB	±0.2 dB
Level adjustability		±0.5 dB	±0.5 dB
Max. overall change in any audio frequency.	±Hz		±2 Hz
Stability of multiplex frequency generator Initial setting to-			2 parts in 10^8
Drift per month			2 parts in 10^7
Single tone interference	24 dBaO		
Max. data/telegraph levels, single channel high speed.			(FSK) —13 dBmO
Speech level			(AM) —10 dBmO —15 dBmO

Notes:
1. The noise power shall be divided such that 5,000 pwp is assigned to the multiplex equipment and 20,000 pwp to the transmission media.
2. The allowable transmission media noise in a section of length L nautical miles (L less than the 6,000 nautical mile reference circuit) is found by ---

$$\text{Noise} = \frac{L}{6000} \times 20{,}000 \text{ pwp} = 3.33L \text{ pwp}$$

3. The total noise shall not exceed 316,000 pwp (49 dBaO) 1-minute mean value more than a cumulative 0.01 percent of the worst month.

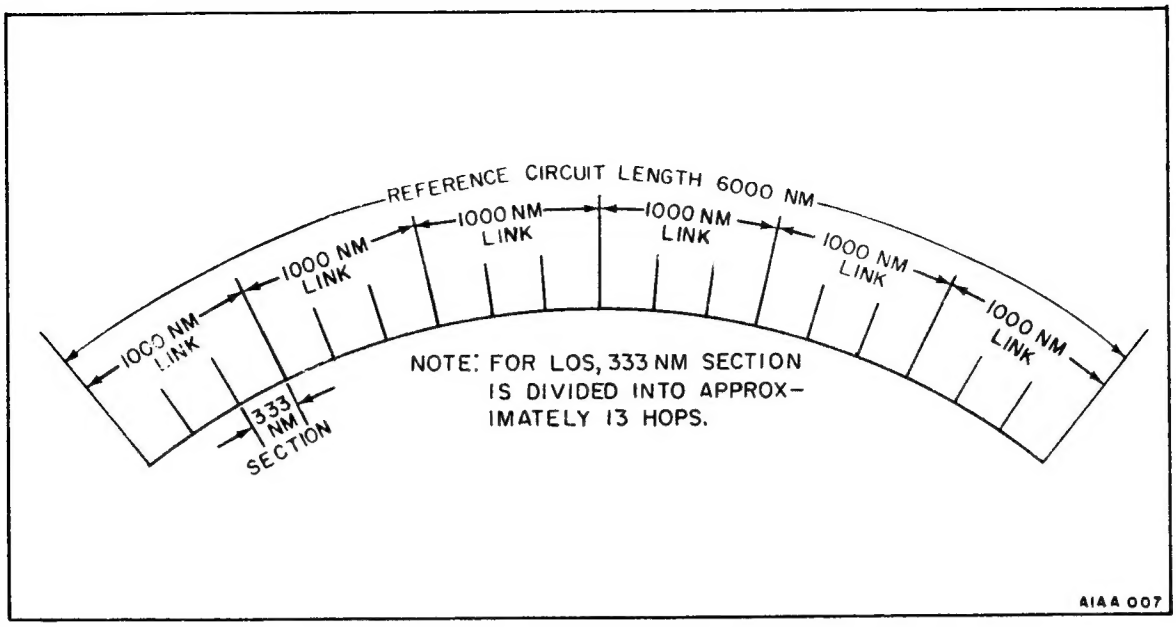


Figure 1-6. DCS Standard Reference Hop, Link and Section Allocations

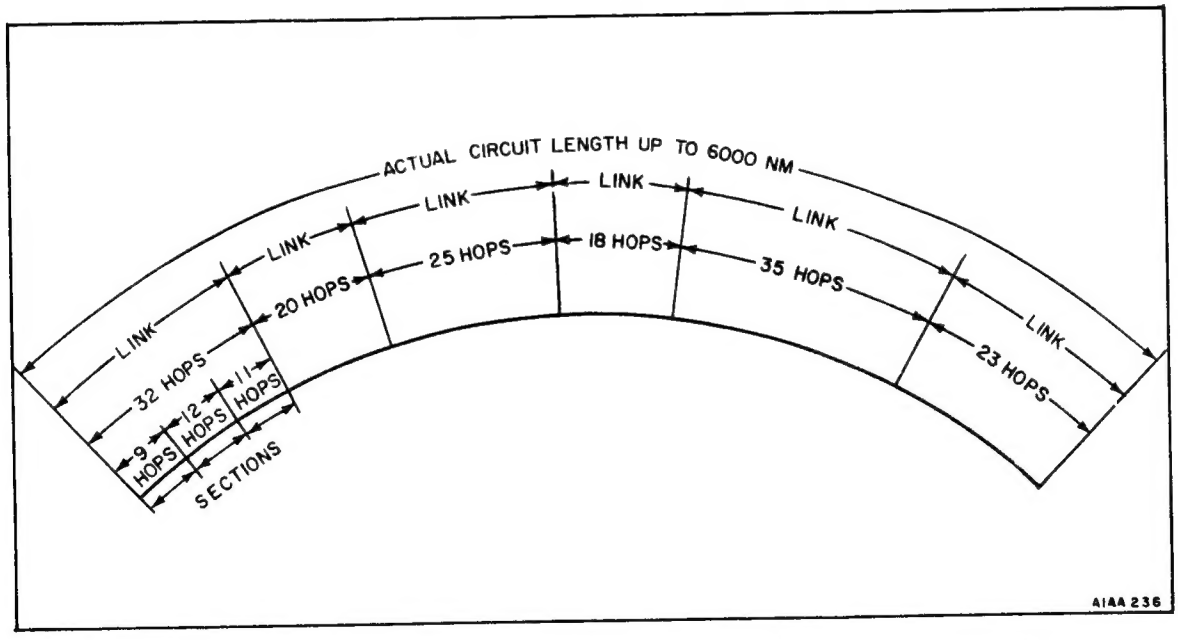


Figure 1-7. Typical Arrangements With Hops, Sections, and Links of Various Lengths

specifications. RF signal levels listed in the figure are only an indication of approximate value since the actual levels will be determined as part of the calculations included in this handbook.

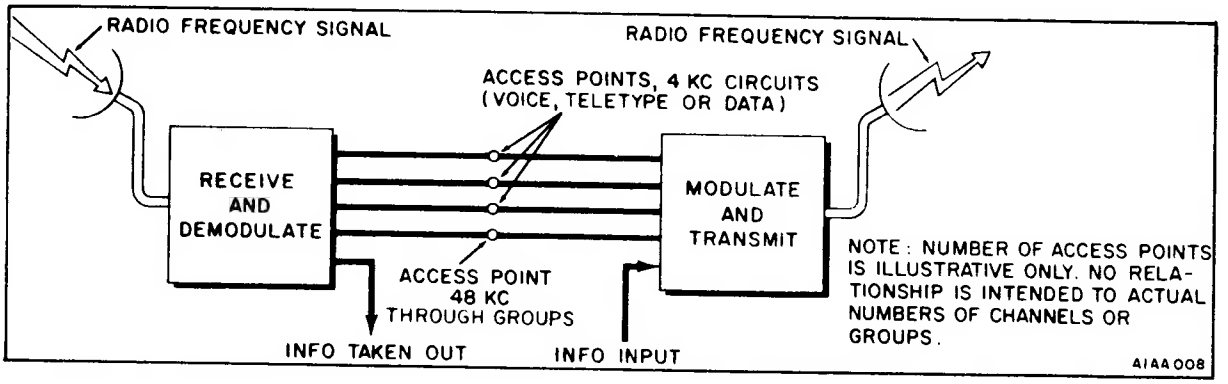


Figure 1-8. Interface Between Reference Circuit Links

1.2.3 Tropospheric Scatter System Reference Circuit

The DCS Reference Circuit as applied to tropospheric scatter microwave systems is illustrated in figure 1-6. The 333 NM Section is the nominal length of a tropospheric scatter hop.

In practice, geographical and communications requirements will dictate the actual terminations and lengths. Consequently the DCS transmission specification must be pro-rated on a per mile, per hop or per section basis. The basic transmission media noise (N) for a tropospheric scatter hop (or section) shall not exceed

$$N = 3.33L \text{ pwp median during time block 2}$$

or exceed

316,000 pwp for more than a cumulative L (.02) percent of time block 2.

where L is hop length in nautical miles.

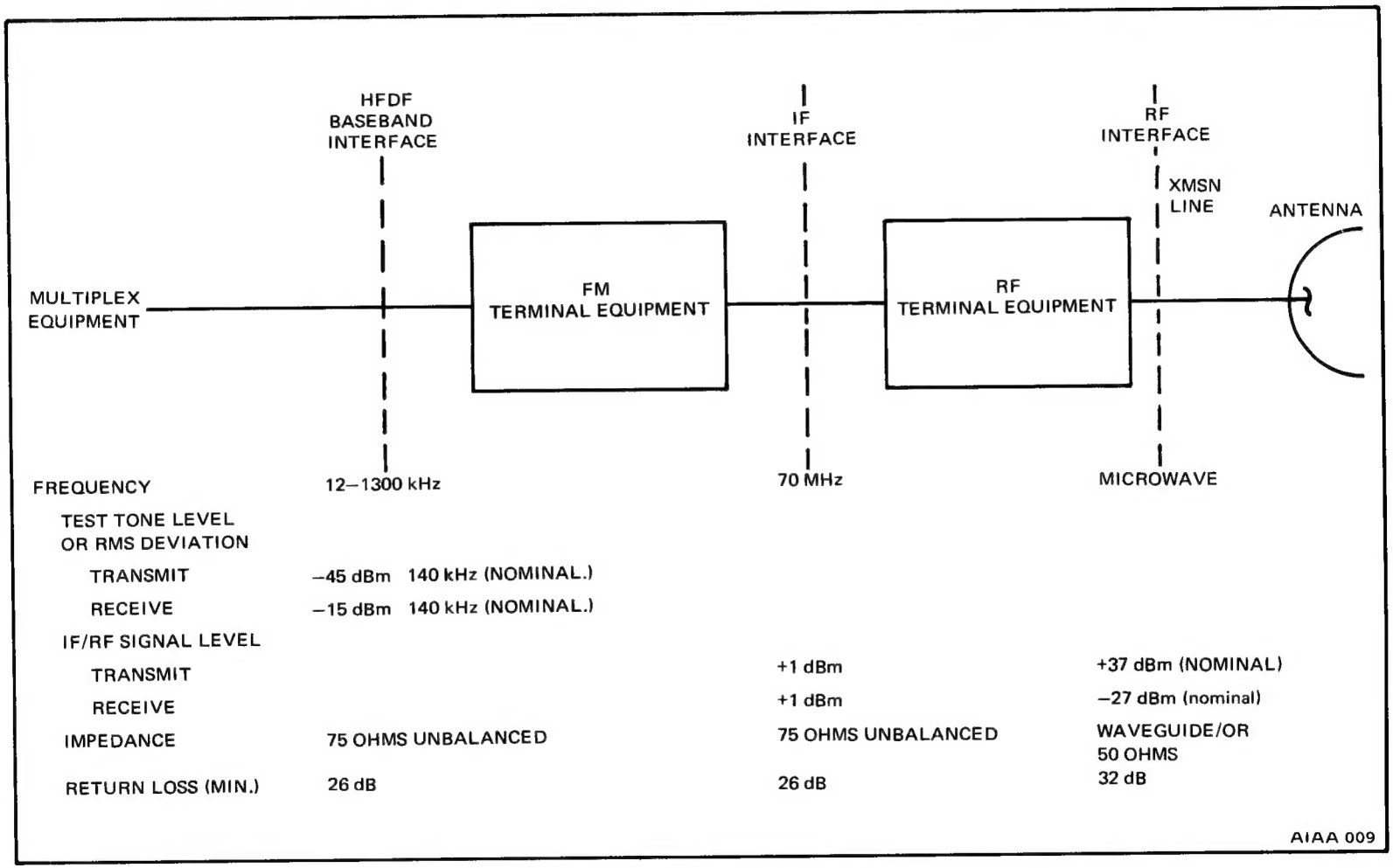


Figure 1-9. LOS Microwave Terminal Interface Parameters

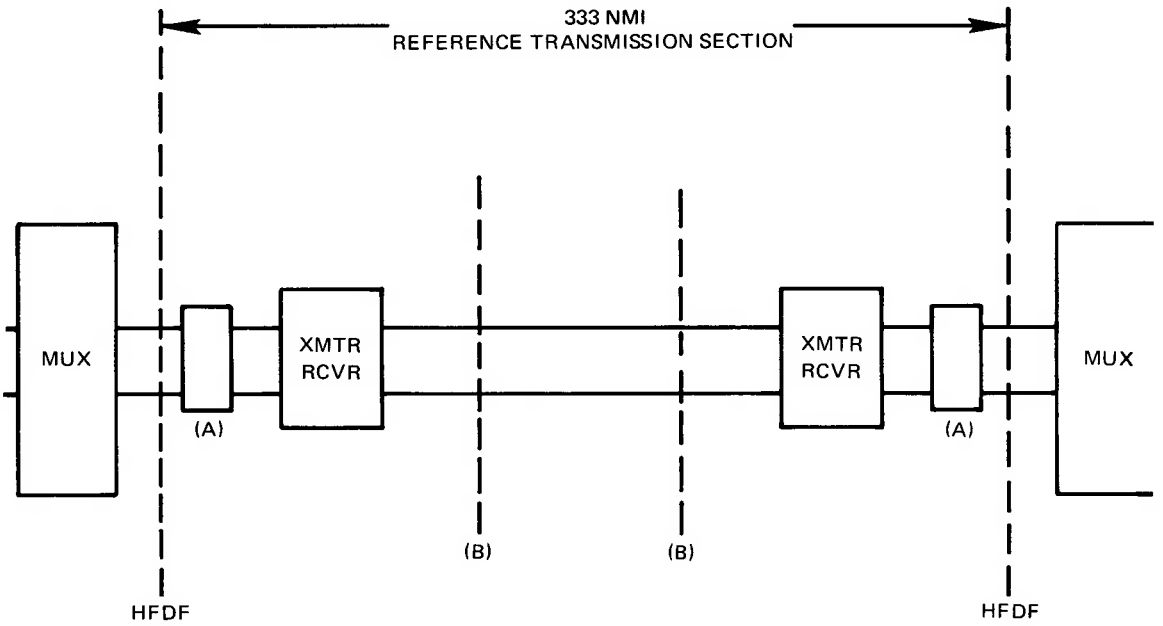
It is not expected that each hop will meet these noise limits, some hops will be better and some worse, however, the cumulative noise power from all hops in tandem within the 1000 NM reference line shall meet the criteria. To achieve this it is often convenient to analyze the system performance in terms of tandem hop performance.

The basic transmission media noise (N) for tandem hop performance shall not exceed

a. N = 3.336 pwp median during time block 2

or b. 316,000 pwp for more than a cumulative $\frac{L}{100}$ (0.1) percent of time block 2

Figure 1-10 shows a nominal Troposcatter transmission section and figure 1-11 identifies the various interface parameters and their specifications. The RF signal levels are not specified since their levels are determined as part of the calculations included in this handbook.



(A) – TRANSMISSION LINE FACILITY INCLUDES LINE CONDITIONING EQUIPMENT SUCH AS PRE–EMPHASIS NETWORKS, AMPLIFIERS, AND PAD AS REQUIRED.
(B) – REPEATERS AS REQUIRED.
HFDF – HIGH FREQUENCY DISTRIBUTION FRAMES

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Figure 1-10. DCS Reference Transmission Section

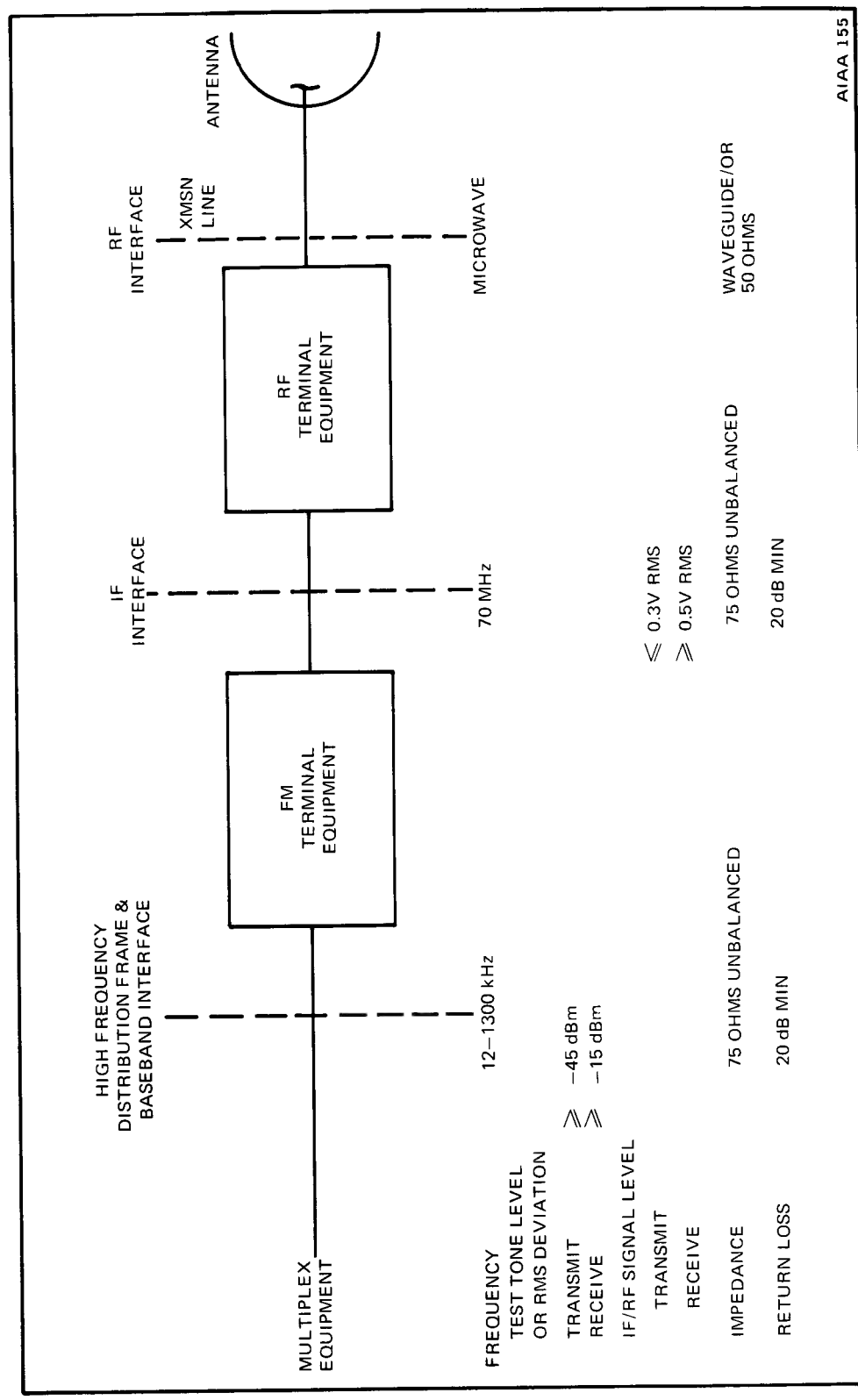

Figure 1-11. Troposcatter Terminal Interface Parameters